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ABSTRACT

The capabilities and applications of interactive video in science education are examined in four chapters. Chapter 1 discusses technology in science education, providing a comparative evaluation of interactive videodisc (IVD) systems and the microcomputer. Specific uses of microcomputers in science education are noted. Chapter 2 is a discussion of the current state of science education, considering: the theoretical base/conceptual framework/goals and objectives in science education; teachers; textbooks; curriculum; inadequate resources; declining enrollment; and public and federal support as well as financial and budgetary considerations and attitudes. Chapter 3 offers insights into the role of the laboratory in science education. Chapter 4 focuses on the problem areas in science education and laboratory settings and on how IVD systems may help alleviate some of those problems related to laboratories and to the areas addressed in chapter 2. Specific recommendations are offered when applicable, cautioning that proper in-service training for teachers and users of these systems is needed. Bibliographic citations and a paper by John C. Ittelson titled "Videodisc and Microcomputer Applications and Software" are provided in the appendices. (JN)

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Chapter 1

Technology in Science Education

It can be stated unequivocally that science education in the United States is in crisis and badly in need of reform in order to keep abreast of a rapidly changing technological society. Any attempt to cite the numerous studies on this subject within one paper would be a formidable task. Despite the divergence in recommendations to bring about reform, it is universally agreed that reform must occur soon if we, as a nation, hope to bridge the ever widening scientific and technological gap between the United States and other industrial nations.

Innovation and reform could become synonymous in the context of high school science education. If the current methods have failed, then it is time to incorporate new, innovative technologies into our educational systems.

The purpose of this paper is to examine one such technological advancement, that of interactive video, its capabilities and applications in high school science education. Additionally, an overview of the current state of science education in the United States, laboratory problems and recommendations for change will be presented.

1.1 Interactive Videodisc Systems and the Computer - a Comparative Evaluation

IVD SYSTEMS:

Computers may be the apple of many an educator's eye, but an interactive videodisc system offers that same educator the whole orchard. The computer, standing on its own merits, offers a supplemental system to an existing educational program, while an interactive videodisc system offers the student an integrated simulation device with the capability of expanding the physical environment and overcoming educational limitations of the same program. Stated simply, the computer provides logical processing and the videodisc a vast storage of visual information.

It is not the purpose of this chapter to advocate interactive videodisc systems over existing computer systems, but rather to present an overview of what exists as well as the capabilities of both.

The introduction of interactive videodisc (IVD) systems for use in public school settings is a fairly recent phenomenon. Its prominance as an effective educational tool can be traced to the military who annually spend $13 billion on general and educational training. The public sector has recently begun to recognize IVD capabilities which has resulted in IVD systems being labeled "the ultimate educational tool" (Currier, 1983); "a breakthrough in instructional technology of potentially revolutionary import to educators" (Levin, 1983); and "the most exciting innovation for computers today" (Instructional Innovator, 1983). As the technology is refined, costs reduced and public school acceptance is increased, it is anticipated that IVD systems will become an integral part of public education systems.

In the interest of convenience and expedience, a composite of IVD components, capabilities and uses will be presented in Figure I.

Figure I represents a summary of the elements of interactive videodisc systems as viewed by various leaders in the field. A brief description of an interactive videodisc model developed by Dr. John C. Ittelson will provide clarification on how these elements can be drawn together to develop an interactive video delivery system. (For full clarification of the model refer to Appendix A.)

Dr. Ittelson (1982) states that there are five elements common to all interactive delivery systems: User, Input, Output, Control, and Media. The user is the individual interacting with the delivery system. Input is the means by which the user communicates with the delivery system and can vary considerably from key pads and touch sensitive screens to graphics tablets, audio inputs and various other controls. Output can include audio, still frames, visual motion sequences, computer data, hard copy, even digital and analog outputs, and in some interactive systems computer graphics are superimposed over video. Control is simply any type of computer giving intelligent control. This can vary from large mainframe computers to personal computers or dedicated "black boxes" that control the interactions based on the computer programs designed for them. The last element is that of media, which physically contains the learning materials: examples are videodisc, videotape, floppy diskettes, firmware, and other digital on analog storage media.

By reviewing the information provided in Figure I, one can readily see that the user/student has the opportunity to go beyond traditional linear, passive educational methods and become an active participant. For instance, because of a design technique referred to as branching, which creates alternative routes through a given set of program materials, students have the capability of proceeding at their own pace, making choices of what they need to see, testing their comprehension and completing remedial work in areas where needed (Currier, 1983).

A clarification of some of the less obvious terminology listed may give the reader a clearer understanding of what an interactive videodisc system can do.

Motion decomposition - the capability to display each of the 54,000 frames independently showing every movement in an action sequence by using the freeze frame mode (Currier, 1983).

FIGURE I: INTERACTIVE VIDEODISC COMPONENTS, CAPABILITIES AND USES

COMPONENTS:

VIDEODISC

integrates color, sound and action
high access speeds
high information density
extremely durable
high picture and sound resolution
frame-by-frame forward and reverse capabilities
stable single frame
rapid single frame access
can store up to 54,000 frames and 20 hours of still frame audio
reproduction cost low $10-25
initial press run $2000-3000
ability to store all information formats, i.e. printed page, art prints, static slides, dynamic motion film, video tapes and digitized or analog data

Types:
- capacitance: relatively inexpensive, uses electronic stylus to read stored information on surface.
- reflective optical: retrieves information from light reflected off smooth surface by use of laser beam, no physical contact with disc, offers 30 and 60 minute playback modes.

VIDEODISC PLAYER

Models:

- consumer: less versatile; less costly; personal use
- industrial: more costly; offers greater complexity for interactivity; uses internal microprocessors

Levels of interactive capabilities:

- level 1: basic performance functions of consumer models
- level 2: use of memory capabilities in industrial disc player provides branching to different disc segments in response to learner choices
- level 3: use of outside computer for control

MICROCOMPUTER

adds versatility
provides immediate feedback
provides learner interaction
adds possibility of generating computer graphics over disc images
provides control of instruction
provides random access
provides for branching

MONITOR

variety of commercial or industrial TV or computer terminal screens

CAPABILITIES:

USER CONTROL

access program at any time
jump from area to area at will
review
skip ahead

USER INPUT BY

computer keyboard
disc player panel
hand held remote control pad
paddle or joystick
light pen
touch of screen
voice activation

USER MANIPULATION OF

forward
reverse
slow/fast motion
stop frame
dual audio channels
chapter stops
single motion sequence access

GENERAL

motion decomposition
masking
simulation of "real life"
instant remediation
addition of orientation information
highlighting of information
ability to draw hidden data paths
composite video image menus

USES:

learner paced/individualized instruction
training manuals/programs
demonstration tapes
travel guides
movie mapping
people skills/role playing
catalogs
health education and prevention
entertainment
educational laboratories
automated salesmen
shopping arcades
encyclopedias
electronic tutors
object disassembly

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(Above information was drawn from the following sources: Levin, 1983; Business Week, 1983;

Object disassembly - an object is displayed on a screen (i.e. engine carburetor system), the student touches a marker on the screen, the screen zooms in on that area and the student may continue to touch the screen until that object is completely disassembled. The student can access the part of the equipment he or she wishes to work on and then learn to reassemble it properly (Currier, 1983).

Masking - a system by which a portion of the screen is "masked" when an incorrect answer is given until the student has been directed to the correct answer (Currier, 1983).

Simulation - a representation of "real life" through the use of motion, color and sound via a TV or computer monitor.

Simulation is an important variable and should be clarified in terms of its use and significance in interactive videodisc systems. The following scenario may help in understanding what is meant by a representation of "real life."

"A student chooses two test tubes from a rack, pours the contents into a beaker, heats the mixture. Suddenly it explodes. As a lab simulation the test tubes, beaker and explosion would all be on video. Shots coded onto a videodisc and played back by commands given to a microcomputer" (Currier, 1983).

IVD simulation goes beyond the traditional modes of educational simulation and extends the classroom environment, overcomes the limitations of available equipment, broadens the capabilities of the teacher and offers the student and teacher an expanded resource to the world around them such as the use of simulation for vicarious travel.

In the most traditional educational sense simulation could be defined as:

> "placing the individual in a realistic setting where (s)he is confronted by a problematic situation which requires his/her active participation in initiating and carrying through sequences of inquiries/decisions and actions" (McGuire, 1976)

Lunetta and Hofstein (1981) indicate that traditional modes of educational simulation include collecting and processing data from secondary sources such as photographs and films; construction of 2 and 3 dimensional physical models; activities which are analogous to the phenomena being studied; media-controlled interactions; people controlled interactions (role-playing); and, students developing their own model for a phenomenon or system.

Whether simulation is used in the traditional or technological sense, it helps facilitate understanding of complex systems, affords the opportunity to experience otherwise dangerous situations and to use expensive equipment that may not have been readily available to the student (Lunetta and Hofstein, 1981).

Additionally, Lunetta and Hofstein (1981) state that simulation in education provides students the opportunity to become actively involved in:

"1. experiencing phenomena not normally accessible because of administrative, technical or economic constraints
2. developing certain kinds of inquiry and problem-solving skills (interpreting data, hypothesizing, communicating, decision-making)
3. developing understanding of certain concepts and models."

A synopsis of the varied uses of interactive videodisc has been provided in Figure I; however, a brief discussion of existing IVD programs directly related to science education would be appropriate. At this writing, few IVD programs exist for high school science education; however, as the technology advances and is recognized as a viable educational tool for use in public education, an abundance of new programs will emerge.

Selected Sample of IVD Programs:

1. The Puzzle of the Tacoma Narrows Bridge Collapse (John Wiley and Sons)
   * physics oriented
   * demonstrates collapse of Tacoma bridge
   * student must draw hypothesis and draw conclusions based on wind and bridge composition factors

2. Interactive Videodisc Science Instruction Project (Nebraska Videodisc Group)
   * 3 discs directly related to physics, biology and chemistry labs (college-based)
   * designed for individualized lab experiences

3. The Development of Living Things (WICAT Systems)
   * 8-15 hours of individualized instruction in developmental biology

4. Bio Sci Videodisc (Videodiscovery)
   * biology related courseware

5. STARS - Space Time Army Reconnaissance System
   * military based program simulations of space, mapping, decision making

6. THOROUGHBRED - The Series by Master Teachers
   *educational software , game form, covers biology, math, social science and chemistry for teenagers

7. OPERATION: FROG - (Scholastic Software of New York)
   *designed for simulation of frog dissection, promotes scientific method and deductive reasoning

8. HES - (Human Engineered Software)

*series covering immunology, oceanography, physics and chemistry for home computer use

Leaders in the field:

University of Nebraska
Nebraska Videodisc Design/Production Group
Lincoln, Nebraska
leading center for interactive video research
produced wide variety of discs (40), designs workshops,

WICAT Systems, Inc.
Orem, Utah
most active contributor to interactive video field
authoring systems

Perceptronics
Woodland Hills, California
develops primarily interactive video applications for military use
performance simulators, surrogate travel, instructional systems, information systems and video games and entertainment

National Education Corp.
Newport Beach, California
has developed a write only optical disc drive which stores image and digital data

University of Iowa
Iowa, City
active in a variety of interactive videodisc projects since 1978

Wiley & Sons
New York, New York
published the Tacoma Narrows Bridge Collapse

Actronics
Pittsburgh, PA
designs, develops and markets computer-based educational systems with videodisc use

Courseware
San Diego, CA
interactive videodisc projects in health and rehabilitation
designer and provider of instruction and training

Drew University
Madison, New Jersey
produced discs and supporting material for the Space Disc Series

Massachusetts Institute of Technology
(Architecture Machine Group)
Cambridge, Mass
vicarious travel interactive video
leaders in the more exotic interactive video applications

United States Military
have funded various interactive videodisc projects
ranging to surrogate to tank maintenance

Utah State University
Logan, Utah
site of the Videodisc Innovations Project
faculty contributions to videodisc literature

Interactive Video/84 by Applied Video Technology of St. Louis, Missouri provides a current and accurate listing of all those persons and institutes involved in producing or developing interactive videodisc systems today and acts as a valuable resource to anyone seeking more information about the field.

Problems are inherent in the implementation of any new technology and despite the rave reviews that IVD systems have received, there are problems to be overcome here as well. In addition to a simple lack of knowledge, paramount concerns include cost; the dearth of good IVD educational programs; incompatability of software and hardware; and most importantly, teacher, administrative and school board resistance.

1.2 The Microcomputer

The year 1971 was an historic year with the advent of the microcomputer. Intel provided the technology and chemists such as Jonathan and Christopher Titus, David Larsen and Paul Field helped integrate this new technology into education (Rafert and Nicklin, 1982). Since that time microcomputer use in education has increased markedly. A 1982 report by Market Data Retrieval Company showed that one-third of the nation's schools now own and use computers in their educational systems (Instructional Innovator, 1983). As an example of the rapid increase in instructional use in public schools the following figures were also provided by Market Data (The Journal of Computers in Mathematics and Science Teaching, 1983-84):

	SCHOOLS
1981	15,318
1982	24,696
1983	54,050 (estimated)

When the educational capabilities were recognized a good seller's market was established. This resulted in a proliferation of poorly thought out and executed educational software. In addition, all this new technology meant that teachers and students were required to become computer literate in order to run these programs.

Before discussing microcomputer use in education a brief examination of the advantages and disadvantages will be undertaken.

ADVANTAGES:

- small and versatile machine
- memory power
- graphics ability
- offers one-on-one learning
- instant feedback
- programmable for self-pacing
- helps establish good study habits (CMI)
- good motivational tool
- simulates experiments that otherwise could not occur
- easy computation of problem calculation
- receive data and graph it immediately
- classroom management tool
- offers drill and practice
- can be used as an electronic blackboard

DISADVANTAGES:

- considerable initial expense
- poorly written computer software and literature
- time element for learning use of computer
- lack of space for terminals
- how to interweave the computer into existing programs
- many programs are not designed for beginners

- software and/or hardware may become rapidly outdated
- economically disadvantaged students have limited access to computers

(Instructional Innovator, 1983; Nakhleh, 1983; Rafert and Nicklin, 1982)

MICROCOMPUTER USES IN SCIENCE EDUCATION

drill and practice
tutorials
games
simulation
teacher's aid/classroom management
modeling
laboratory instrumentation

Computer Managed Instruction (CMI) and Computer Assisted Instruction (CAI) incorporate the first six items on this list and will be discussed later. Of interest to the application of science education is the use of the microcomputer as a laboratory instrumentations device.

Bob Tinker (1981), director of TERC's (Technical Educational Research Center) states that "a computer can be used in the laboratory as a universal instrument to generate signals, gather and analyze data and display results. With the advent of microcomputers and other developments in electronics, the cost of computer-based instrumentation is far less than conventional instruments with comparable performance and easily within the reach of many schools."

General applications include counter-timers; TC testing; function generator; Fourier synthesis; transient recording; Fourier analysis; radioactive half-time; pulse height analysis; rotational and linear dynamics. (Tinker, 1981)

CMI and CAI constitute the basis for most microcomputer educational use and can be defined as follows:

Computer Managed Instruction - "Management of information relating to instruction and to the delivery of certain kinds of information relating to record keeping for students and teachers" (Nakhleh, 1983).

Computer Assisted Instruction (CAI) - "Using computers to provide information to students" (Nakhleh, 1983).

USES OF CMI AND CAI PROGRAMS

CMI:

- recording of tests
- wordprocessing
- student records

- test diagnostics
- statistical analysis
- scheduling
- inventory
- student performance evaluation
- homework assignments
- individualized assignments

CAI:

- tutorials
- drill and practice
- game format
- problem solving
- review
- enrichment
- acceleration
- self-paced instruction
- demonstrations
- simulations

(Nakhleh, 1983; Instructional Innovator, 1983; Zalewski, 1982)

Both CMI and CAI programs provide options that are beneficial to the management of the classroom and help alleviate unnecessary paperwork for already overburdened teachers; however, CAI uses constitute the majority of microcomputer educational systems. NSF's report "Educating Americans for the 21st Century" (The Journal of Computers in Mathematics and Science Teaching, 1983-84) indicated that the advantages of CAI programs are that they proved to be a more effective mode of instruction than conventional methods; that teachers are able to develop their own learning materials allowing for tailoring to the needs of students; cost of materials is moderate; it is well suited for home-based learning; there is little need for teacher intervention and it permits the student self-paced learning.

Whitehurst (1981) lists five distinct advantages specifically related to CAI in science education:

1. simulations of lab experiments provide an excellent opportunity for students to practice techniques before performing an experiment

2. models and case studies can be examined

3. games provide enjoyment, enrichment and an opportunity for review

4. provides for use of electronic blackboards for tutorials and drills

5. can be used as a laboratory instrument

Problems which occur in using microcomputer systems and IVD systems are similar and vary only in relationship to the number of educational programs offered in the field of science. It would be a formidable undertaking to list all the existing CAI science programs, so for the purposes of this paper a representative sample will be sufficient.

PILOT (Kolodny and Bayly)
Introductory chemistry with Apple-based pre-lab quizzes

PLG (Starkey and Kieper)
Pre-laboratory quiz for organic chemistry and laboratory safety

Comptrol Lab (EduTech, Inc)
Pendulum and acceleration lab experiments Physics

RAIN (Smith) Chemistry game organic and inorganic compound study

Organic Chemistry (Smith)
Tutorial supplement with simulated experiments

Qualitative Organic Analysis (Johnson)
IR Spectra and identification of organic compounds

CCL Earth Science Curriculum
Cross sectional analysis
Graphic fault displays sequencing events

Weather Fronts (TYC Software)
Lesson - tutorgraphs

Chem Lab Simulations (Gelder)
Four programs for understanding chemistry

It is evident in the review of the information presented that IVD capabilities far exceed those of the microcomputer. The IVD changes the dimensions of computer simulated CAI programs and offers the student "real life" situations that go beyond the "flat" dimensionality of computer graphing. However, because IVD systems incorporate the use of microcomputers, the educator is given the distinct advantage of being able to use existing CAI and CMI programs and still have the extended capabilities of the IVD system. An appropriate analogy may be that microcomputers are two dimensional in nature while interactive videodiscs are three dimensional in their educational capabilities.

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Chapter 2

The State of Science Education Today

Gerlovich and Downs (1981) believe that the United States economy and society are based on technology premised on scientific concepts and to compromise this in education would be hazardous to the individual and society. It is interesting to note that a nation that once prided itself as being the leader of industrial nations has now fallen far behind other industrial nations in educating its children for a technological society.

Science and mathematics are an integral part of our lives. The study of science and mathematics provides the content and models necessary for the development of the critical decision making and problem solving skills used in leadership and management. However, Boffey (1982) notes that many individuals are not competent to make wise choices in everyday life, to perform effectively on the job, to note and carry out civic responsibilities and to exercise political leadership.

Additionally, we cannot expect the people of this nation to manage a society based on science and technology if adequate educational training in those fields is not provided. Unless we provide the executives and leaders of tomorrow with adequate science and mathematics education, they will be ill-equipped to handle a science oriented, technological society. Nuclear safety, chemical food additives and sophisticated military weapons are examples of political issues whose resolution requires technical awareness and knowledge (Boffey, 1982).

If we consider that in 1982 there were 331,600 life-science and biology classes in junior and senior high schools around the country with an average of 22 students per class, then we have the responsibility of educating an estimated 7,295,200 students in one science area alone (Sterba, 1982). The magnitude of the problem is evident when an estimated 90% of all Americans are scientifically and technologically illiterate (Science Education Data Book, 1980).

What do the experts feel is the underlying reason for this decline? There is no consensus; however, the following are felt to be some of the disciplines major underlying problems:

- no solid theoretical base or conceptual framework for the science disciplines
- lack of well-defined goals and objectives

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- teachers preparation and education
- availability of adequate texts
- lack of cohesive curriculum
- declining enrollment
- public and federal support/attitude/knowledge
- financial and budgetary considerations

In terms of percentage of overall problems in the field of science education, Yager's Et al (1982) study of science educators showed that areas of concern included:

1. confusion and uncertainty in goals and objectives (60%)
2. lack of vision and leadership in schools and universities (43%)
3. public and parental apathy toward and misunderstanding of science and science education (39%)
4. limited budget and facilities (38%)
5. poor quality and low standards of teacher education practitioners (31%)
6. limited scholarly dialogue among the three of us teachers and practitioners (31%)
7. declining enrollments (26%)
8. lack of theoretical base for science education (25%)
9. lack of programs to meet varied needs of students (24%)
10. lack of appropriate inservice programs (23%)

Each one of these issues will be addressed with accompanying recommendations for change.

2.1 THEORETICAL BASE/CONCEPTUAL FRAMEWORK/GOALS AND OBJECTIVES IN SCIENCE EDUCATION

One of the major complaints of science educators and scholars is that there is not a solid theoretical base, conceptual framework or adequate goals and objectives by which to base a science program.

Hurd (1982) states that despite the many attempts to establish a conceptual framework and define major goals for science teaching, agreement among experts has not happened. In fact the common result was that the educational researchers and practitioners have come to avoid the issue. He also feels that a characteristic practice in science education research has been a constant effort to add new data to an old problem rather than seeking new methods to deal with that same problem or even perceiving new problems.

Hurd (1982) further states that we function ahistorically and atheoretically resulting in an inability to bridge the gap among science, society, technology, human values and science teaching. As a result, guidance for resolution is sought from outside sources such as research scientists, scientific societies and federal agencies.

Yager Et al (1982) indicate that there is a clearly perceived need for change and this need is based on newly identified problems which render old goals and objectives ineffective. Furthermore, a prominent factor contributing to the problems in science education is the dissimilarity of the goals of science education and the current state of science, society and educational theory.

Conceptual problems determined as significant in a recent survey of science educators included confusion and uncertainty in goals and objectives (69%); lack of theoretical base (25%); lack of vision and leadership (43%); and to some extent lack of professional identity and legitimacy (Yager Et al, 1982).

Hurd (1982) suggests that the development of a strong conceptual framework for science has failed because of how the science education community approaches the task. The question is posed; the "rap" session begins; every member offers his/her personal bias; a report must be developed within the mandatory time constraints; arbitration begins over the conflicts of interest and competing judgements; and concensus is made when the competing conceptual ideas are stated in ambiguous terms with blurred statements.

Recommendations for Change:

If, as defined by Yager (1984), "science education is the discipline concerned with the study of the interaction of science and society and their interdependence becomes a reality and the interlocking concept for the discipline," then conceptual changes should reflect this need.

The following represents a composite of recommendations made by leaders in the field:

Kahl and Harms (1981)/Project Synthesis Broad Goal Clusters:

1. Personal Needs: science education should prepare individuals to utilize science for improving their own lives and for coping with an increasingly technological world.

2. Societal Needs: science education should produce informed citizens prepared to deal responsibly with science-related societal issues.

3. Academic Preparation: science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge appropriate for their needs.

4. Career Education/Awareness: science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.

Yager (1978) Unique Goals:

1. Enhancement of intellectual development through knowledge of the universe, things and events; understanding of generalizations; and learning through manipulation and self-discovery.

2. Learning of coping skills for successful application of knowledge in making decisions related to a wide range of problems, i.e. social imperatives for survival.

3. Provide for opportunity to check forecasts and alter trial generalizations through personal manipulation.

4. Develop a set of positive values and attitudes toward scientific and technological developments and their wise use by society.

5. Science is important as a "basic skill" essential to one's total learning and includes science and its application in the world.

Hurd (1982) Criteria for Science Education Framework:

1. The current condition of scientific enterprise and the mode of scholarship of the contributing science disciplines.

2. The impact of science on the social process and the interactions characterizing the science, technology, society, values paradigm.

3. The persistent science/society problems and issues that characterize our culture.

4. The conditions of knowing and the cognitive and affective attributes essential for rational behavior in a science/technology-based society.

5. The flow of contemporary intellectual currents of ideas, empirical generalizations, perspectives and human priorities that are salient for developing a conceptual framework for science education.

Yager Et al (1982) Theory and Learning Goals:

1. Establish a theory base to guide science teaching and research which reflects the nature of science, learning and compatibility with other educational goals.

2. Establish clear set of goals for science education for K-12 and teacher education that reflects a theory base.

3. Theory base must reflect the nature of science and the nature of the human as a synergistic whole.

4. Reflect that achievement of science goals enhances basic skills performance.

5. Emphasize the philosophic foundation of science and lessen the so-called psychological foundations of learning.

2.2 TEACHERS

When problems arise in the quality of education our children receive, the educator generally becomes the "dumping ground" for that problem. The problem is too far reaching to blame on a single source; however, there are problems specifically related to science teaching.

Aldridge (1981) indicates that the low priority given to science education in schools, the reduction in teaching resources and materials, inadequate salaries and a general lack of support have been instrumental in producing the critical shortage of secondary school physical science and math teachers. The Annual Report for the National Education Association (1983-84) reported that the total number of physics teachers who graduated from all Wisconsin higher education institutions in 1981-82 was one. In 1982-83 there were two, with similar figures in other states. Thirty-eight states are currently reporting shortages of chemistry teachers, forty-three states, math teachers and forty-two states, physics teachers (Dede, 1983).

Of equal importance is the majority of the current science teachers are not qualified to teach that subject. The National Commission on Excellence in Education's report "A Nation at Risk" (1983) indicates that half of the newly employed mathematics, science and English teachers are not qualified to teach these subjects and fewer than one-third of United States high schools offer physics taught by qualified teachers. This problem is compounded by the fact tBhat many of those teaching science maintain an attitude that there is little perceived value in having students become scientifically literate (Gerlovich and Downs, 1981).

Other teacher related problems listed by Gerlovich and Downs (1981) are lack of teacher planning time, a belief that science is less important than other subjects, and a lack of teacher interest in science. Additionally, teacher layoffs in high schools will force younger, unskilled teachers into science and math classes, as well as forcing those older more experienced teachers into an outside job market where economically they fare much better (Aldridge, 1981). With the demand in the industrial job market for skilled scientists, our public school systems fall back on physical education teachers with a minor in sciences to teach the science classes. A study by Weiss (1977) showed that

only 22% of science teachers felt qualified to teach their subject matter area.

A lengthy study conducted by Karplus (1977) indicated that poor achievement and concept understanding by science students was a direct result of science teachers who lacked understanding of differing developmental reasoning patterns in their students. He felt that Piaget's developmental theory on providing concrete physical interaction between the student and his environment to enable the student to progress toward more formal thought should be strongly recommended to teachers of science.

Yager's Et al (1982) study of science educators' perceptions of teacher related problems indicated that the programs designed to prepare science teachers for the classroom are of poor quality and that few teacher education programs give teachers an adequate understanding of the nature of science and its relationship to society. Of equal importance is the inappropriateness of teacher inservice programs.

Recommendations for Change:

Varied solutions have been suggested for alleviating the teacher crisis in science education and include: retaining teachers; use of retired persons, industrial personnel and unemployed persons of the community with science skills; special scholarships and loans to attract people into the field; and, salary adjustments and bonuses (Gardner and Yager, 1983). However, following represents a composite of recommendations made specifically for ameliorating teacher related problems:

1. "Increase the number, kinds and availability of inservice education programs;

2. Examine existing teacher education programs and attempt to identify theoretical orientations that have relevance for classroom practice;

3. Devise means that will enable science teachers to integrate graduate work in science education and continued work in the classroom;

4. Ensure that the education of science teachers considers not only the fundamentals of science but the fundamentals of education as it interfaces with society" (Yager Et al, 1982).

The National Commission on Excellence (1983) recommended changes in the educational aptitude standards for teachers of science and math specifically with increased competency in the academic disciplines.

Other recommendations included increased salaries in order to be professionally competitive, adoption of an 11-month contract for curriculum and professional development, development of career ladders, use of nonschool personnel resources to solve teacher shortage, incentives to attract outstanding students to the teaching profession and the use of master teachers to design teacher preparation programs.

2.3 TEXTS:

Considering the magnitude of the problems in science education today, textbooks may seem an unimportant issue; however, because our educational system has often been labelled "textbook bound" it bears examination. Gabel (1983) points out that a recent survey showed that 90-94% of 12,000 science teachers used the text 90% of the time. Project Synthesis, a National Science Foundation supported research project, indicated that when a curriculum becomes textbook bound a decision has been made about what textbook is to be used, the curriculum set and from that point on curricular decisions are made based on that book. In essence it becomes the authority and source of information (Anderson, 1983). If that is indeed the case, then the following statement made by the National Education Association in their 1983-84 annual report may be of consequence:

"Science texts are so poor, so diluted, bland, disorganized and sometimes inaccurate that many experts advocate forsaking them usually unnecessary. If used at all, they should be left on the shelf as resources and picked up only in moments of desperation."

Gabel (1983) states that because publishers choose to limit the size of the book by condensing the material, the textbook becomes quite useless as a learning tool and topics become so superficial that students tend to memorize vocabulary rather than learn the concepts. She further states that in an attempt to keep the texts updated, the publishers make one of three choices - they expand, delete or condense the text without consideration for location of the descriptive material resulting in fragmentation of concepts.

Other findings show that too few experienced teachers and scholars are involved in writing textbooks; that the texts are so easy that the majority of the students are able to master 80% of the material before they open the books; and that expenditures for textbooks and other instructional materials have declined by 50% over the past seventeen year (The National Commission on Excellence in Education, 1983). Additionally, the most widely used textbooks devoted only 10% of their content to personal needs, societal issues and career preparation (Anderson, 1983).

Recommendations for Change:

Overall, research on textbooks is limited, resulting in a scarcity of recommendations for textbook improvement. The National Commission on Excellence in Education (1983) makes the following recommendations:

1. textbooks and other learning and teaching tools should be upgraded
2. educational and professional experts in the fields should assist publishers in the development of texts and materials

3. states and school districts should carefully evaluate materials and texts and require evaluations to insure effectiveness

4. funds should be made available to develop texts for disadvantaged students, the learning disabled and the gifted and talented

5. publishers should furnish evidence of the quality and appropriateness of texts

6. new instructional materials should reflect current applications of technology, scholarship and research

Additionally, texts should reflect the four area goals formulated in Project Synthesis: societal issues, career education, salient knowledge, and personal needs (Harms and Kahl, 1981). B

2.4 CURRICULUM

Science curricula and overall curricular requirements at the secondary level have been badly neglected in the United States. Compared to other industrial nations our science and mathematics curricula are substandard. For instance, Japan, with half the population of the United States, graduates more than 2.5 times as many engineers as we do. Twenty-two percent of the bachelor's degrees and 40% of the master's degrees in Japan are in the fields of science and engineering, while in the United States the combined figure for both degrees, in both fields, is approximately 5%. In Germany math begins in grade one, biology in grade three, chemistry and physics in grade five, and algebra in grade seven. The importance placed on math and science studies in these countries does not diminish as the students progress into the upper grades. In the United States fewer than one-third of all school districts require more than one year of science or mathematics in grades 9-12; one half of all high school graduates have taken no math or science beyond grade 10 (Gardner and Yager, 1983). These are merely two examples of many, but one can readily see the inadequacies in our curricula.

Weiss (1978) reported that the national average for the number of minutes teaching reading amounted to 105 minutes per day, while science amounted to a sum total of 17 minutes. On the elementary school level the average was a whopping two minutes of science per day. This is far below the recommendations made in the study entitled "Educating Americans for the 21st Century" which set a minimum of 60 minutes per daily requirement for math and 30 minutes for science for students in K-6. One full year was required for both subjects in 7-8 and four full years for 9-12 including computer technology (May, 1983).

The National Commission on Excellence in Education (1983) indicate in their study of education in the United States that compared to other nations, American students spend much less time in school; time spent in the classroom and on homework is used ineffectively and that schools do not help students develop good study skills.

Todays "basic" school curricula does not generally include science as an integral component despite the fact that science instruction is fundamental to learning "basic" material in other disciplines (Gerlovich and Downs, 1981).

Anderson (1983) states that research studies show that science education in the United States is exclusive, academic and largely devoid of inquiry orientation: 1. exclusive because high school programs do not provide direction to the general education student required to take math and science to meet minimum high school competencies, but rather are geared toward the needs of the more able college bound student. 2. academic because of the selective attention directed toward narrowly defined academic science knowledge and little attention directed toward personal needs, societal issues and career preparation. 3. devoid of inquiry orientation because the majority of the teachers reject it as a teaching method. This is not necessarily an indication that inquiry orientation is not an effective teaching method, but may be a direct result of other factors influencing the education environment.

Anderson (1983) further notes that curriculum theorists agree that three sources determine the content of the curriculum: the individual, the society and the discipline. Science education in the United States is based almost entirely on the discipline.

The purpose of this section is not to enumerate the many problems of science curricula in the United States, but rather to concentrate on the recommendations for change.

Recommendations for Change:

To reiterate, the recommendations made by Kahl and Harms (1981) taken from the Project Synthesis study represent a composite of broad-based goals which promote inquiry teaching. These include a stress on recognizing personal needs, societal needs, academic preparation and career education and awareness. These goals attempt to make science education more relevant and not so discipline bound. To keep in line with their goal cluster, Project Synthesis recommended that programs at the elementary school level would actively involve the children in gathering data; problems would be presented in a definable, possible to accomplish manner and be an outgrowth of first-hand experiences; and, all problems would be real. At the junior high level materials used would focus on issues and topics related to personal, societal and career choice; and decision making and problem solving skills would be emphasized, particularly those related to problems faced by individuals and society. At the high school level activities would be expanded in all areas of science reflecting personal, societal and technological needs (Volk, 1984).

Anderson (1983) stresses that there is a need for a change in graduation requirements; inservice education for teachers; teacher involvement in curriculum decisions; an involvement of non-school resource persons; a careful study and analysis of curriculum guides, textbooks and actual classroom curriculum experiences; development of new curriculum guides; update testing programs; and use outside science education consultants when necessary.

Additionally, there has been a call for more homework; development of effective study and work skills; increased school hours; better classroom management and

organization; a change in attendance policies; reduction administrative burdens; and, academic placement of students according to instructional needs rather than by age (National Commission on Excellence in Education, 1983). All these problems indirectly effect curriculum decision and should be considered of importance.

The Commission (1983) also suggests that high school graduates should be provided with an introduction to (a) the concepts, laws and processes of the physical and biological sciences; (b) methods of scientific inquiry and reasoning; (c) the application of scientific knowledge to everyday life; and (d) the social and environmental implications of scientific and technological development.

The National Education Association Annual Report (1983-84) recommends massive staff and curriculum development at the elementary school level, emphasizing the study of science from K-12; special emphasis on programs for students of low and mid-level ability to help close the science illiteracy gap; less reliance on textbooks and more on modular units and computer software packages; de-emphasis on isolating the sciences; and, an emphasis on the "how" of science rather than the "what."

Other leading experts reiterate what has already been said and the commonality in their recommendations is reflected by their insistance that curriculum development be relevant and reflect personal, societal and technological needs.

Models of curricula development will not be discussed in this section as they vary so widely and are too numerous to list. Examples of these models include a systems approach, embedded curriculum, vertical atriculation, directed instruction and a new strategy developed by the Educational Technology Center at Harvard known as "targets of difficulty" (ETC, 1984).

2.5 INADEQUATE RESOURCES, LABS AND FACILITIES

This problem will be addressed in Chapter III of this paper.

2.6 DECLINING ENROLLMENT:

This is not a variable which can be controlled and projected statistics do not relate directly to science education but are generalized in nature. The effects of declining enrollment, however, are encompassing. For instance, declining enrollment effects financial support, which in turn effects programs, the student and society in general.

Aldridge (1981) points out some fairly alarming facts about declining enrollment. During 1980-1990 there will be a drop of 19% in the number of 14-17 year olds in the United States which means a loss of one million students in grades 10-12. This does not include the millions who drop out of school before the 10th-12th grades. In conjunction with this, there will be a reduction of 110,000 teachers during the same period. Shifts in population from the north states to the south and western states will also result in reductions in both teachers and students in those sections of the country.

Enrollments will pick up from 1990-2000 in the 14-17 age group as well as in elementary students, but it may be at a time when the number of qualified science teachers is at its lowest point. If this results, the citizens of America may not be prepared for an increasingly complex technological world and will reduce the United States to a third-rate status in relationship to other industrial countries (Aldridge, 1981).

Those enrollment declines directly related to science education and which may be controllable are directly related to curriculum development and attitude. The development of appropriate curriculum requirements and a strong scientific educational base will be discussed later in this chapter. The development of appropriate attitudes so that students don't drop out of sciences at an early age should be a major undertaking of the schools, parents, community and educators. General skepticism of science in conjunction with little science emphasis in high school curricula for the majority of the students results in 50% of the students taking their last physical science class by the 10th grade (Gerlovich and Downs, 1981).

Recommendations for Change:

Recommendations for change concerning an uncontrollable variable would be a difficult task; however, the problem may take care of itself as a result of the current baby boom.

There were no recommendations for change made in the research directly related to decline in the enrollment of science classes; however, addressing curriculum and attitude changes would be of paramount importance.

2.7 PUBLIC AND FEDERAL SUPPORT; FINANCIAL/BUDGETARY CONSIDERATIONS/ATTITUDES

These three categories have been lumped together because in many ways they are interrelated. Without maintaining an appropriate attitude about the significance of science education, public and federal support, which is synonymous with financial support, will not happen.

Allen (1983) noted in his survey study of the use of technology in science education that a high degree of the student respondents quoted their parents' attitude as their own. If this is indeed the case, then there may be a cycle of negative attitudes toward science maintained from generation to generation.

Overall public opinion of the importance of science education is so low that in the current push for a "back to basics" format in education, sciences have not fared well and have been pushed, symbolically speaking, to the back of the class. In a survey conducted by Yager (1982), it is noted that public apathy toward science and science education was felt to be a major problem by 40% of the educators responding. Additionally, the educators felt that the guidance which parents provided their children in selecting science courses was minimal at best and that apathy was apparent by the minimal fiscal and public support given for science instruction.

It is interesting to note that this is contradictory to the National Commission on Excellence in Education's report, "A Nation at Risk" (1983). They state that "people are steadfast in their belief that education is the major foundation for the future strength of this country. They even considered education more important than developing the best industrial system or stronger military force and that public education should be the top priority for additional federal funds." Belief in the value of education is one thing; economic support is another matter.

Helgeson (1978) reports that the cost of education is a major national concern and cited several surveys to support this premise. School financing was a dominant concern, rating financial disaster as the number one problem in education. Interrelated problems include inflation, the decrease in purchasing power or educational budgets, decreasing enrollments which directly affect the budgets available for science education, less emphasis on science education at the federal level and a decrease in state and local level support.

When revenues become constricted and salaries are reduced at a rate that does not keep abreast of inflation, then many quality educators (particularly in the sciences) are forced to find alternative careers. This results in a reduction in the quality of education, which leads to public dissatisfaction and then to a reduction in monies allocated at the state and local level (Dede, 1983). This is yet another example of a perpetual cycle that throws science education into a downward spiral.

The National Science Board Commission feels "that the government does have some responsibility in ensuring that its citizens are trained to meet the demands of the workplace and a society that increasingly requires mathematical, scientific and technological skills and understanding" (May, 1983).

Federal support of science programs has been on hiatus for the past three years, but recently has allocated $1.5 billion in start up costs for improvement of the nation's mathematics, science and technology programs for elementary and secondary schools. More than half this money would go toward helping state and local governments set up "exemplary programs" (May, 1983).

Recommendations for Change:

As economic considerations exert pressure on our educational systems, there is a call for federal financial support for the enhancement of our educational programs. However, despite increased funding for the enhancement of these programs, improvement may not occur if there is not a marked change in attitude toward science education. The changing of these attitudes, however, will be a

monumental task because it will involve the "re-education" of families, communities and, unfortunately, science educators. Anderson (1983) notes that significant change does not occur without local initiative. Innovations in education do not come without local level support such as parents, members of the community and students. This is the level at which resources can be allocated to science improvement.

The public's support and commitment may be the key to change. As the National Commission on Excellence in Education (1983) states, "of all the tools at hand, the public's support for education is the most powerful." The public is the electorate, and the electorate can effect change.

Additionally, the Commission recommends that principals and superintendents play a crucial leadership role in developing school and community support for the reforms; that state and local officials have the primary responsibility for financing and governing the schools and incorporate reforms; that the Federal Government, in cooperation with States and localities, should help meet the needs of groups of students such as the gifted and talented, socioeconomically disadvantaged, minority and language minority students, and the handicapped; that the Federal Government provide support of curriculum improvement and research on teaching, learning and the management of schools, support of teacher training in areas of critical shortage; and provide students financial assistance and research and graduate training; that the Federal Government has the primary responsibility to identify the national interest in education; and, that educators, parents and public officials at all levels are to assist in bringing about the needed educational reform.

Obviously there is grave concern about how science is being taught in our schools today; however, as seen in this chapter, there is no universal agreement on what action is needed to rectify this problem. For change to occur, the concerns in this chapter and those in Chapter 3 will need to be addressed, not by a single source, but by a proper mix of resources. For a single source to attempt to address all the recommendations for change made in this chapter alone would be beyond their human and financial resource capabilities.

Chapter 3

Laboratories - Essential to Science Education

Science educators of the past several decades have recognized the importance of the laboratory experience in the teaching of science education. Because they recognized this importance funding was made available directly for this purpose. This was evident particularly in the 1950's and 60's as every secondary school curriculum project funded by the National Science Foundation utilized laboratory investigation as a major teaching method (Crabill, 1980). However, despite these earlier funding efforts somewhere between the 60's and 80's this importance diminished to the point that now the majority of our school laboratories and those teachers required to teach lab procedures within those laboratories fall short of even being called adequate.

During the past 20 years tremendous expenditures of federal, state and local funds have been provided for science facilities, materials and equipment, but evidence shows that these materials and equipment are not being used as had been expected (Crabill, 1980). In a study conducted on 76 major school systems (Glovinsky, 1962) in 1962, out of 20,000 junior and senior high science classes 37% did not have laboratories. Further non-laboratory classes were larger than laboratory classes and designed for slow learners.

How important is the lab experience to science education?

The National Science Teachers Association Board of Directors unanimously endorsed the necessity of laboratory experiences for teaching and learning science. They called for adequate support for materials, equipment and teacher time for the schools to maintain quality science instruction (Klein, Yager and McCurdy, 1982).

Voltmer and James (1982) state that "science content coupled with science laboratory gives students a 'lever' on manipulating and understanding their environment. Terminology in the absence of the experiences with materials and its effects is an ineffective way of building scientific concepts for most students." High school lab time, however, can be measured in minutes for students. Rarely is one activity continued for more than 90 minutes, the average length of lab periods, which includes set-up and clean-up and must be subtracted from the 90 minutes. It is estimated that this leaves the student with an average of 75 minutes for productive work per week per class (Nagel, 1982).

The lab experience is important because:

- laboratory instruction has been instrumental in increasing overall achievement scores in science at the middle/junior high level (Tafel, 1982)

- the laboratory is one of the few places in a school environment where students can use "inductive" reasoning (Tafel, 1982)

- the laboratory gives the student an opportunity to actually do science rather than just sitting and passively learning about science (Perez, 1982)

- the laboratory provides the "hands on experience" that is necessary to help the student integrate the processes that characterize science as a discipline (Perez, 1982)

- the laboratory develops the skill of inquiry, the search for order and the significance of the natural environment (Perez, 1982)

- the laboratory is the place where the student can learn living skills, i.e. decision making and problem solving (Perez, 1982)

- the laboratory experience provides a powerful tool for developing reading and mathematics skills (Lunetta, 1982)

- laboratories encourage the students to become better observers, more cBareful thinkers, better users of information, more deliberate problem solvers, more curious observers of the environment, and more logical thinkers in approaching the unknown (Lunetta, 1982)

- laboratory experiences help develop student skills such as: recognizing problems; selection and use of data collecting procedures; manipulation of materials and situations for making relevant observations; drawing inferences, generalizations and concepts from data; predicting unknown; applying information; and communicating with others to resolve problems (Lunetta, 1982)

- the laboratory has a greater potential of nurturing positive student attitudes toward science than content learning (Bates, 1982)

- the laboratory provides a wider variety of students the opportunity to be successful in science courses (Bates, 1982)

- laboratory experiences are superior to lecture or demonstrations for learning to use equipment (Bates, 1982)

- time spent in laboratories contributes positively to the learning experience and does not impede content acquisition through standard lecture and text modes (Bates, 1982)

The preceding statements clearly display the strengths of the laboratory experience in science education; however, as a result of the "back to the basics, minimal competency" movements, and financial constraints on education, there has been a decreased emphasis on science specifically reflected in

process and laboratory activities in the classroom (Gerlovich and Downs, 1981).

Additionally, studies conducted by Crabill (1980) and Voltmer and James (1982) show that not only do many teachers lack the competencies to teach laboratory procedures, but also choose not to teach in the lab if given the opportunity. Crabill found in his survey of 362 secondary science teachers in Washington, D.C., that on the average only 28.4 percent of science instructional time was spent in the laboratory setting. Voltmer and James (1982) state that because many teachers do not have the skills to successfully conduct laboratory-based instruction, the lab is not used to its fullest potential, if at all. Many laboratory procedure subject areas covered in laboratory teaching competency programs were deemed inappropriate by the teachers because they required sophisticated, expensive equipment and a moderate degree of skill to use them safely and effectively with students. Interestingly enough, safety competencies such as handling, storage and disposal of laboratory substances, and knowledge of correct and incorrect procedures to handle student injuries were rated as a low priority by teachers for competency requirements. Despite the lack of teacher interest in safety competencies, a vast amount of research and information has recently been published on the subject. Safety in laboratories will be discussed later on in this chapter.

What factors influence use of laboratories by science teachers? Of greatest significance for laboratory use by teachers is that teachers who actively participate in the National Science Foundation Institutes are more likely to be involved in lab activities and inquiry type learning processes than those who do not participate (Highwood and Mertens, 1972). Inservice program trainings showed significant changes in attitude and behavior toward lab use among science teachers who chose to take advantage of the trainings (Jackson, 1970; Hansen and Billeh, 1975). Sex, age and years of teaching were also significantly related to successful science teaching (Davis, 1964 and Brown, 1965). White (1970) felt that teacher academic preparation was important in promoting increased lab activity use for science students. Other variables include salary level, adequacy of the lab and the size of the class (Grobman, 1964).

A study was conducted by Noojin Walker in 1982 on the content of high school Chemistry courses. 140 high schools and junior colleges in Mississippi were surveyed. Results of the survey showed that high school teachers do not agree among themselves on lecture topics to be taught in high school chemistry - out of 50 laboratory topics only 4 topics were agreed upon for inclusion in the classroom laboratory setting, but 39 were agreed on for exclusion; that junior college chemistry teacher's assumptions of what was being taught in high schools was incorrect resulting in an inappropriate educational interface; and, that coordination between high schools and colleges was inadequate and ineffective. Walker quotes Ausubel as saying "that meaningful learning occurs when the learning begins with what someone already knows and leads him to the discovery of something he did not know." This may not happen if a general concensus on programming does not occur.

The physical setting for laboratories in science education is an important issue, as many facilities have neither the proper space nor the proper equipment for adequate instruction. These variables are controlled at the state and local levels. Most states have developed criteria for a proper lab

setting, but often financial restrictions prevent actualizing these criteria.

As an example, the following is representative of criteria the state of California has formulated for the development of physical settings in science classrooms in California public schools:

1. entire school plant and community should be considered in planning process

2. setting should be flexible for large or small-group instruction, lab activities, outdoor experiences, etc.

3. facilities considerations:

    3.1. tables and sink highly desirable (elementary grades)

    3.2. safety and storage of volatile and flammable chemicals and liquids (secondary)

4. safety:

    4.1. precautions essential

    4.2. equipment and materials should be examined regularly for hazards

    4.3. classroom should be organized to facilitate supervision

    4.4. limit the group size

    4.5. allow sufficient time for each activity

    4.6. use of safety glasses/goggles urged

    4.7. activities should not be allowed if facilities or equipment are not appropriate

5. animals:

    5.1. use must conform with local policy and California codes

    5.2. must be housed and cared for in a humane way

    5.3. no pain, drugs or medication (Science Framework, 1978)

You will note that the criteria place a high degree of emphasis on safety. In reference to the previously stated low priority placed on safety competencies, a survey of safety in chemistry labs in Alabama schools showed that 73% of the teachers saw the need for a chemistry safety module for the high schools; students in few schools had adequate knowledge concerning the correct use of available body protective equipment such as fire blankets, safety showers, and eye-wash fountains and, in most cases, they were unaware of the hazards of laboratory equipment and chemicals. Many schools had improper storage procedures for chemicals and lacked proper disposal methods and many were deficient in systematic accident reporting, first-aid facilities and first-aid

personnel (Ekpo, 1981).

Woodburn's survey (1981) of the safety procedures in the secondary schools of Nebraska showed that inexperienced teachers had significantly fewer accidents than those who had been teaching for several years; there were fewer accidents in small schools (1-250 pupils) and significantly more in schools with 501-1000 pupils; fewer accidents with small class enrollments (1-10) and the more enrollment increased, the accidents increased; fewer accidents in physics and significantly more in physical sciences and chemistry; there were twice as many accidents at the junior high level than at the high school level; more accidents in buildings designed with combination lecture and laboratory areas; and, the larger the square footage per student, the fewer accidents. Further, it was concluded that the hazard areas of heat, glassware and chemicals accounted for 80.72% of the accidents recorded.

Other types of safety problems which specifically relate to larger public educational systems include:

- too many students per class; overcrowding can cause accidents and breakage
- inflexible scheduling can cause shortened lab periods which may result in shortcuts and little time to think through a problem
- shortened lab periods do not allow the students to ask questions about nonspecific directions in lab manuals, i.e. "slowly add" or "cautiously stir" (Nagel, 1982).

Other areas of specific interest in the research included liability and negligence suits, legal waste disposal and use of toxic chemicals in high school labs.

Who is responsible? Generally the teacher and even in extreme cases the publishers of lab manuals. It is the teacher's responsibility, if the facilities are not ideal, to modify the lab activities for safety. It is even the teacher's responsibility if a student is hurt when not following lab instructions properly. And it is the teacher's responsibility to educate the students on the proper safety procedures (Nagel, 1982). The last statement of responsibility is interesting in light of information given previously. However, if a teacher exercises proper instruction, adequate supervision and proper equipment maintenance, then liability and negligence cease to be an issue (Gerlovich, 1983).

Waste disposal:

Without listing the numerous chemicals and processes for disposal, the general rule of thumb for safe disposal of chemicals used in a classroom besides not dumping unknown chemicals down the drain or outside on the ground, would be: "Nonhazardous waste chemicals can be disposed of as you choose. All hazardous waste chemicals can be disposed in conformance with federal, state or local regulations. So-called small quantities of hazardous waste are most conveniently put into lab packs and transported to a landfill for proper burial by a permitted landfill facility" (Young, 1983).

Toxic chemicals:

There are several areas of concern when speaking of toxic chemicals in the classroom: exposure limitations; routes of entry into the body, i.e. inhalation, skin absorption, skin and eye contact and ingestion; proper use of chemical combinations; and, chemical reactions to skin contact. With proper safety procedures, problems in these areas can be avoided. Again, teacher responsibility (Nagel, 1983).

Chemical storage:

Williamson (1983) provides a very succinct list of don'ts for chemical storage:

- don't store in alphabetical order
- don't store water sensitive chemicals in a water sprinkled storage area
- don't store solvents in anything but vented cabinets
- don't store chemicals by reactivity class or by compatibility and don't store non-reactive chemicals together
- maximum separation of reactive chemicals equals minimum risk

Lab safety tips are far too numerous to list here; however, key recommendations generally include adequate teacher education in overall lab safety and use; maintenance of facilities; knowledge of chemical use and disposal; and, developing good mandatory lab practices among students.

And what of lab animals? Three factors have contributed to "saving" a variety of lab animals from lab experimentation over the past few years: microcomputers, economics and "animal rights."

Many labs, particularly higher education laboratories, have begun to use microcomputers instead of lab animals. The University of Texas Medical Center in Austin has reduced its use of lab animals by about 12% and projects a reduction of 40% in the future. Saving lab animals saves money, i.e. laboratory dogs cost about $50, must be fed and cared for (Magid, 1983).

High schools generally can only afford smaller animals/mammals such as frogs or rats. Economic factors have reduced funds for buying supplies for labs and that adds up to fewer frogs for experimentation. In the Sputnik era of science education frogs by the millions were shipped to classrooms because federal dollars were available to science programs. Frogs were purchased to enrich the science experience, following the "hands-on" philosophy. Suppliers estimate that during this era nearly 100 million frogs gave their lives for science. The 1960's saw an era of conscientious objection to the killing of lab animals with the enactment of the Animal Welfare Act of 1966, but despite this, by the end of the 70's frog supply was nearly depleted (Sterba, 1982).

Sterba goes on to say that because of the recession the frog population is making a resurgence, but schools are unable to buy them. At one time there were two students per frog. Now there are four students per frog. The direct

contact is limited and understanding of how animals function internally is minimal at best.

This scenario on frogs was merely another example of how budgetary cutbacks have effected the quality of our overall laboratory experiences. As stressed throughout this chapter on laboratories, direct "hands-on" lab experiences are of paramount importance to understanding science, its concepts and how it relates to everyday life. The necessity for hands-on type of experiences are expressed in Piaget's theories stressing learning as an active process involving manipulation of one's own environment in order to develop the appropriate mental structures that will eventually allow the student to attain the highest level of intellectual development - formal (abstract) thought (Crabill, 1980). Innumerable studies have incorporated Piaget's theory in their instructional methods; for instance, Bybee (1970), Babikian (1971), Merkle (1973) and Herron (1966) all show significant increases in concept learning among students who participate in laboratory exercises.

Further studies conducted by Bybee and Hendricks (1972) indicated that physically handicapped, disadvantaged or slow learning students who were involved in science laboratory activities showed positive or significant gains when direct hands-on experience with objects was involved. This manipulation of concrete objects was essential to their overall concept formation. Significance was also shown in concept understanding for deaf children and problem solving for inner city children due to manipulation of objects and materials (Boyd and George, 1973).

Chapter 4

The Problem and CIVD

This chapter will focus on the problem areas in science education and laboratory settings and how Interactive Videodisc Systems may help alleviate some of those problems. To reiterate, the following problem areas will be discussed:

*theoretical base/conceptual framework
*goals & objectives
*teachers
*texts
*curriculum/content
*declining enrollment
*attitudes
*financial & budgetary concerns
*laboratory settings: physical setup, time constraints, special issues

THEORETICAL BASE/CONCEPTUAL FRAMEWORK

It would be absurd to think that the problems of developing a strong theoretical base or conceptual framework in science education could be solved by a single system such as IVD. This has become an academic and political issue that has been immersed in ambiguity and indecision for years. However, a pertinent question would be whether we should wait for the leaders of science education to develop a concensus on a broad conceptual base or should we move forward and look at a new technology such as IVD to help solve the problems that currently exist in the science educational field. There may never be a concensus in the science field and conflicting interests may result in ambiguity on what needs to be done, but strongly developed IVD systems may offer a much needed boost in the continuity of science educational systems. A strong theoretical base and conceptual framework could be developed within the confines of a well thought out, well designed IVD educational system which would include goals and objectives that address relevant, contemporary science, societal and educational issues. A well developed IVD system could:

- *provide for personal needs by providing the student with a broader base of simulated "real life" experiences from which to draw, as well as interaction with current technology.

- *address societal needs by providing relevant science issues which effect society today; i.e. pollution.

- *provide for appropriate academic preparation through self-paced/individualized instruction.

- *provide the student with an expanded awareness of the career opportunities by providing a broader base of information.

- *enhance intellectual development by broadening the students scope of the universe, events, etc. through visual interaction, manipulation and self-discovery.

- *enhance coping and decision making skills by providing practical applications of relevant issues and problems.

- *provide for the opportunity to check forecasts and alter trial generalizations through personal manipulation and calculations.

- *develop positive attitudes and values about science through interacting capabilities and decision making skills.

- *integrate science as a basic skill by providing exercises and information on appropriate applications to the world.

TEACHERS

All of the problems intrinsically related to teachers of science education cannot be ameliorated through the use of IVD's; however, there are a few problems that easily lend themselves to IVD use.

- The use of IVD science programs could act as an important supplement to teachers who are not fully qualified to teach the subject thus providing the student with accurate and updated information and procedures.

- The use of IVD science programs in school districts which have no one to teach specific science subjects provides the students an educational opportunity they would not otherwise have.

- The use of IVD science programs would help integrate relevant societal issues that the teacher may otherwise be ill equipped to address.

- The use of IVD science programs allows the teacher to demonstrate skills safely and economically with no risk to the student or to the existing equipment.

- IVD's can effectively be used for teacher in-service training relevant to their programming needs thus providing the teachers with adequate skills to deal with the rapidly changing field of science and the student with better teachers.

- The use of IVD science programs can help alleviate growing reductions in monies available for classroom materials and supplies by providing "simulated" materials and environments thus providing the student with expanded and adequate experiences.

- IVD systems can be used for student data and records storage thus alleviating some of the time burden placed on teachers.

TEXTS

In light of the concerns presented in Chapter 2 on textbooks, it would appear paramount that a new approach to educating students about the sciences would be necessary.

If indeed our educational systems are "textbook bound" and the majority of the science books are poorly written, diluted, bland, disorganized and inaccurate and the content matter is left to the discretion of the publisher, then the time for an alternative educational tool has come.

Because an IVD system has the capability of providing simulation of "real life," the possibilities for content expansion of a traditional textbook could be limitless. When scientific models, concepts and procedures are taught through simulation, students have a greater opportunity to integrate this information more effectively than through traditional text learning because they are placed in a situation where they are able to interact with the "text" material.

To accomplish the task of making IVD science programs relevant and successful, great care should be taken to include educational and professional experts in the field in the developmental stages to avoid duplicating the same mistakes that current publishers have made. In addition, they should reflect current applications of technology, address societal issues, career education, salient knowledge and personal needs.

To reiterate information provided in Chapter 1, the following represents some of the IVD capabilities for expanding traditional "textbound" information:

*provides simulation thus expands the physical environment
*allows for motion decomposition, object disassembly and masking
*provides for instant remediation
*gives option for addition of orientation information
*highlights important information
*provides for graphic display
*provides visual demonstrations where necessary
*allows students to develop decision making skills
*allows for relevant vocabulary terms to be directly associated with the process through visual observation
*allows for tutoring capabilities
*allows for self-pacing
*allows for a hands-on-type of experience directly associated with the concepts being taught
*provides for instant feedback
*provides for easy compilation of problem calculation
*offers capability for drill and practice
*offers the capability for laboratory instrumentation

CURRICULUM/CONTENT

Science curriculum and content problems are as equally embroiled in ambiguity and philosophical differences as is the development of a strong theoretical base and educational framework. Additionally, local and state politics encumber the best efforts of curriculum design committees through imposed guidelines and regulations. Those issues will not be addressed here, but rather how IVD systems use could help in the areas of time allocated to science content and curriculum; development of study skills; reduction of exclusivity of content directed toward the more able student; expansion of narrowly defined academic science knowledge to include relevant personal, societal and career preparation needs and the restimulation of inquiry teaching.

Time allocation for science and science activities as shown in Chapters 2 and 3 is minimal at best and variables such as class size, set-up time, facility limitations and instructor time constraints hinder the time available for adequately teaching science courses. Technological advances such as IVD's won't add any more time to a 24-hour day, but will help make the time available more efficient and effective. Teachers for instance can utilize CMI capabilities to store information about attendance, inventory, homework, individualized lessons, scheduling and student performance evaluations. In addition, because IVD systems are self-paced, individualized instructional units the teacher is provided with more time during the class period for attending to special needs of the students or expanding and refining the content of their current science curricula. This same self-pacing allows the student the luxury of working within timelines that are specifically suited to that student.

Study skills cannot be forced down a studenBts throat; however, when a student has access to a workstation and the information is available to him or her at a self-paced, individualized level where drill and practice can be performed, their study skills are honed and a transference of knowledge is accomplished. Working in a self-paced, non-intimidating workstation environment with accurate, visual interactive material can stimulate the student to learn material (s)he may have otherwise found tedious and meaningless in a conventional textbook. Often times, due to the lack of available teachers and resources, students are hindered in their pursuit of appropriate science studBy skills; however, IVD systems provide the necessary stimulation which in turn develops interest and activates good study skills.

The issue of exclusivity of content directed toward more capable students can be addressed again through the self-paced, individualized instruction component of an IVD system. A properly designed IVD science program will incorporate a hierarchy of learning that will enable the "slower" student to obtain knowledge and information at his/her own level and speed thus giving a broader base of students the opportunity to learn sciences that they may not have chosen to participate in before. By providing students of low and mid-level ability with programs geared to their capabilities we help close the science illiteracy gap.

The capabilities of an IVD system listed in Figure I, Chapter 1 demonstrate that this type of system offers a limitless resource and extension of the classroom. The potentials are endless therefore making this a perfect medium

for including relevant, up-to-date personal, societal and career preparation information and issues.

During the early 50's science teachers were eager to jump on the "inquiry learning" bandwagon and proved their enthusiasm vis-a-vis a laboratory setting; however, as that enthusiasm waned, inquiry learning techniques and laboratory settings went to the wayside. IVD capabilities offer the teacher and/or student the opportunity to once again learn the "hows" of science rather than just the "what" through inquiry learning processes. IVD lends itself beautifully to the basic concept of inquiry learning - that of discovery techniques which are instrumental to transfer of intellectual skills. This learning system is carried further, not only because of the capabilities for choice, but also because it provides immediate feedback to the learner. Ideally, in this type of discovery learning environment the student should be well on his/her way to attaining the highest order of intellectual development - that of abstract thinking.

The sciences become relevant through visuals and "hands-on" manipulation and the concepts of science can be made progressively more difficult with each advancing grade. By taking one not so definable, hard to understand concept that one might not experience until high school and begin teaching it in the early grades but progressively making it more difficult the student is allowed appropriate integration of the information and the concept becomes meaningful instead of abstract.

DECLINING ENROLLMENT/ATTITUDES

Enrollment decline due to reduction in the number of students attending school is an uncontrollable variable; however, if science class enrollment is on the decline as a result of student attitude and apathy toward the sciences coupled with a poorly designed curriculum, then properly prepared IVD science programs may be the needed stimulus. When one considers the amount of money spent each year on video games and and the fact that the games are played with such enthusiasm and vigor and that IVD systems have some of the same capabilities, it is not difficult to see the potential for regenerating the interest in the sciences. For instance, let us say that in an Environmental Science class you wish to demonstrate what levels of pollution would destroy the environment. This in itself would not be more than mildly interesting to the average student, but if you were to incorporate decision making skills by introducing the concept in a game format, the student's interest would be activated and the concept understood. This, of course, is just one possibility of IVD capabilities; however, it does demonstrate activation of interest. In addition, the actual manipulation, interaction and control given the student is an added incentive for participation and stimulated interest.

FINANCIAL & BUDGETARY CONCERNS

In a time when economic considerations continue to squeeze the life out of our school systems, and more importantly our science programs, school districts should be looking for ways to increase their capabilities in long-term economical ways.

IVD systems may appear costly in the initial outlay of monies to the districts, but once the stations are on-line then the cost economy becomes apparent. The videodiscs can be updated to remain relevant, lab equipment does not become damaged or obsolete, replacement of materials becomes minimized, students get an expanded education (basically more education for their money) and economic considers in terms of teachers, space availability and time allocation experience some degree of relief.

4.1 IVD'S AND THE LABORATORY SETTING

It will not be the purpose of this section to expound on the importance of the laboratory experience to the transfer of knowledge and concept understanding in the sciences as Chapter 3 covers that quite adequately, but rather to discuss how IVD's can work effectively at relieving problem areas such as lab safety, physical environment limitations, lab time constraints and special issues such as handicapped and bilingual students.

Laboratory safety has not been one of the leading concerns of science educators for many years. It has been just recently that a great deal of attention has been paid to this subject due to heavy media coverage. Whether or not it is of concern, safety still remains an issue because any lab setting provides the potential for danger. IVD systems can work two fold here. Firstly, if as stated in Chapter 3 many teachers lack the compentence to teach laboratory procedures and these procedures are primary to lab safety, then IVD science safety units can provaide the student with necessary drill and practice via simulation before they ever approach the "wet lab" situations. Secondly, students can interact and experiment with dangerous and volitile chemicals through simulation without fear of blowing themselves and the lab up. IVD also eliminates the worry of chemical disposal, prevents breakage of expensive equipment and could provide for pre-instruction on how to handle lab injuries if the occasion should arise. In terms of liability, it is easier to sue a teacher for negligence than it is a computer. It is also easier to dissect the same cat via a TV monitor than it is to supply a whole class with enough cats to accomplish the same task.

IVD's become a useful educational tool when overcrowding, shortened lab periods and non-specific directions in manuals become a problem in terms of safety. The self-paced, individualized instruction component of an IVD system allows for non-class time scheduling, helps alleviate the shortcuts that result from time constraints, allows for time to think through a problem and helps eliminate accidents and breakage due to overcrowding. As IVD systems provide for a wide scope of user capabilities, it lends itself nicely to manuals, demonstration tapes, etc. thus providing for thorough instruction manuals and eliminates non-specific directions. Visual examples, coupled with appropriate verbage allows for clear and concise information giving.

The physical setting for laboratories in science are of critical importance. Overcrowding, lack of funds and a movement away from lab related science classes has caused a serious decay in the lab environment. An IVD workstation

takes up only a small portion of the space required by a traditional wet lab. This is not, of course, to suggest that an IVD lab station should replace the wet lab environment, but is merely an example of overall space utilization. It may be more economical, however, in the long run to replace the wet lab with an IVD workstation.

If education is to be provided for all students, then overcoming student limitations should be addressed when developing new programs. It has already been stated in Chapter 3 that lab experiences have resulted in positive and significant gains for the physically handicapped, disadvantaged or educationally handicapped student. In addition, there was a correlation between lab activity and improved understanding of the English language for bilingual students. Many lab situations are dangerous and inaccessible to the physically handicapped. Not so at an IVD workstation - danger is nonexistent and they are accessible. Special science programs can be designed for the educationally handicapped student at their level of understanding. With so few bilingual teachers available and an ever increasing influx of non-English speaking students (particularly in California) an IVD bilingual unit would greatly help alleviate some of the problems in this area.

As shown throughout this Chapter, IVD systems provide some interesting and viable options to help alleviate some of the existing problems in science education today. However, it will be of grave importance to insure that proper in-service training for teachers and users of these systems is accomplished so that this does not end up just another wonderful idea collecting dust on someones shelf. In addition to in-service training, educating the public (i.e. parents, school officials, politicians, etc.) on the importance of systems such as this would be tantamount to its success.

Idealistically, one would hope that IVD systems would help put the United States back on the tract of science literacy.

Appendix A

Videodisc and Microcomputer Applications and Software

VIDEODISC AND MICROCOMPUTERS APPLICATIONS AND SOFTWAR

John C. Ittelson

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Videodisc and Microcomputers Applications and Software

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ABSTRACT

This paper will look at the combination of videodisc technology and microcomputer technology in interactive delivery systems. These interactive delivery systems can be used for training and education using the principles of computer aided instruction and computer based instruction, for point-of-purchase presentations in stores and malls, and for other specialized communications and training purposes that require sophisticated graphics and interactivity. This paper will discuss interactive delivery systems -- the individual components and how they are configured, the team that creates materials to be placed on an interactive delivery system, with particular emphasis on courseware, and courseware evaluation.

INTERACTIVE VIDEO: REVOLUTIONARY?

Since the introduction of the Apple personal computer and the optical laser videodisc in 1978, trade journals and the popular press have proclaimed the "revolutionary" nature of these developments. Given their mass availability and low cost, there is no doubt that these technologies will have a great impact. Yet in my opinion these developments are not revolutionary, but evolutionary in nature.

Since the beginning of time, mankind has used a variety of methods to keep track of data and to perform calculations. Although the memory system of a personal computer is far more sophisticated than knots tied in a shepherd's rope or beads configured on an abacus, it performs the same function of storing data and manipulating them for calculations.

Likewise the use of visual images is not new. Drawings of the hunt on cave walls provided a vicarious experience and recorded detailed information much as do the visual motion technologies, such as film and videotape, that have evolved since then. The videodisc accomplishes the same purpose but far more efficiently. It has been referred to as a generic medium because it is capable of storing slides, film, television programs and computer data. It can store up to 54,000 still frames per disc and, because of its random access capability, has very short access times, usually less than five seconds.

The idea of using computers or video in education is not new. Research on the use of films in training and education received particular emphasis during World War II when the military had to teach very diverse audiences. Since that time researchers have continued to study, and trainers and educators have continued to use, film and more recently, videotape. Computers have also been used in various ways as teaching machines.

When used independently, however, neither video nor the computer was able to deliver quality educational interactions to the level of some of the experimental teaching machines of the early 1950's. B. F. Skinner, who is generally credited with the invention of modern teaching machines, stated the following similarities between the teaching machine and a private tutor in the October 1958 Science magazine: there is a constant interchange between the student and the teaching machine; the teaching machine can keep the student alert and busy; the machine insists that a point be understood before it proceeds, or if not, it presents material in different ways and can help a student come up with the proper answer; and the machine, like a tutor, praises every correct response to reinforce the student's behavior. In this article Skinner also alluded to the limitations of the existing technology, including the fact that teaching machines could show very few kinds of visual materials and had difficulty in accepting anything other than simple multiple choice answers. The teaching machines were not widely available because the time and money necessary to create the delivery systems and courseware were prohibitive.

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A number of attempts were made prior to the introduction of the videodisc and mircocomputer to provide some of the capabilities of sophisticated interactive delivery systems. The Plato system developed at the University of Illinois at Urbana with the plasma screen had rear projection for microfiche, and the TICCIT system used cable with extensive use of videotape for interaction. These systems provided the greatest amount of interactivity to date, but were unable, due to cost and programming problems, to ultimately incorporate the use of the computer and video as well as we can with current technologies.

When defining interactive delivery systems we are really talking about pieces of hardware that, when combined, can provide media resources -- audio from a videodisc or from computer generated speech, or slides or pictures -- to a viewer and can respond intelligently to input from the user in various ways predetermined by a programmer. For example, the system might ask the user a question regarding some information it had just presented in a video segment; depending on the correctness of the student's answer, it would review the material or go on to new information. Two students proceeding through the same courseware would most likely receive different output from the computer, because it would tailor its responses to each student's input. Interactive delivery systems' focus is on their interactivity, and their strength is their ability to deliver a wide range of materials, whether computer generated graphics, computer text, motion picture film, 35mm slides, stereo or monaural sound, all in response to input from the learner.

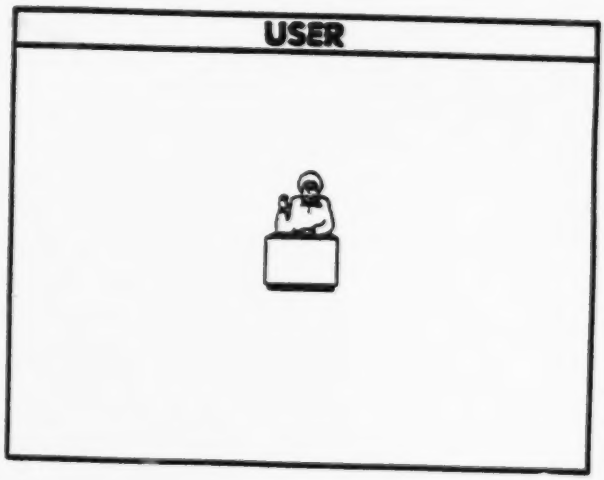
The basic elements of an interactive delivery system - visual images and a controlling device that governs their presentation - merely represent technological refinements, and combining them for educational purposes is also merely a refinement of past experiments. The "revolutionary" nature of the videodisc and the microcomputer is that they have enabled instructional designers to finally put into practice the research of Skinner and other learning theorists. Experiments that were very difficult for the early pioneers in the area of teaching machines, due to the limitations of the technology, are easily done on current interactive delivery systems, and it is that which comes the closest to being a revolutionary concept in the area of videodisc and microcomputer based training and education. Interactive delivery systems have enabled us to worry less about the medium the materials are stored on and more about the way they are presented and how they interact with one another.

A MODEL: THE FIVE ELEMENTS OF AN INTERACTIVE DELIVERY SYSTEM

We will be looking at interactive delivery systems based on videodiscs and microcomputers and at the process by which courseware is created for these systems. We will look first at the delivery systems, for that will provide a framework from which we can describe the process of creating appropriate materials.

A model that Michael Slade of DesignWare and I developed divides an interactive delivery system broadly into five elements. The elements are the system user, system input, system output, system control, and system media. I will briefly describe the elements, their interrelationships, and how they relate to the courseware creation process.

The system user, also called the learner, is anyone who is going to interact with the interactive delivery system. This is the person about whom the instructional designer is most concerned because the better defined and classified the system user, the easier it is to take advantage of the capabilities of the interactive delivery system to create effective instruction. Users of interactive delivery systems since the introduction of the microcomputer and the videodisc have included doctors, lawyers, schoolteachers, technical engineers, gifted children, children with extreme learning disabilities, deaf children -- the list of users is as broad as the population base. More important than the broad base is the fact that usually an interactive delivery system is used by just one person; only in rare cases would groups use it.



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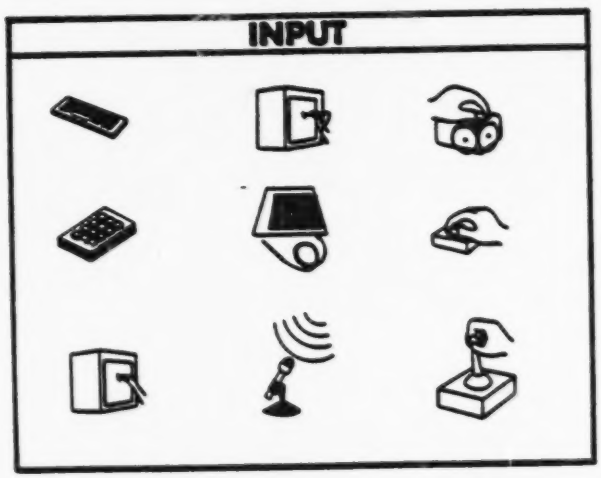
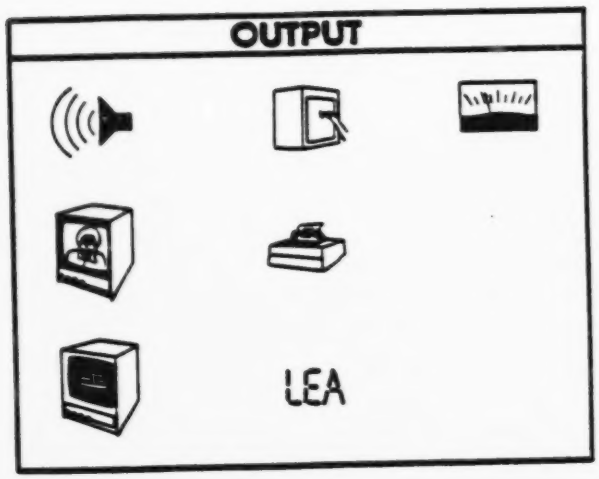
The next element is that of system input, the physical objects the user manipulates to interact with the system. In earlier teaching machines this usually was push buttons that corresponded to specific letters or numbers for responses, but the combination of videodiscs and microcomputers has allowed a greater range in system input. System input can range from simple keypads like those on a calculator, to full typewriter input, to specialized input devices such as touch sensitive television screens, graphics tablets or the use of a mouse. Systems are being developed that use voice recognition as an input device, and the CPR trAining created by the American Heart Association and designed by David Hon uses the resusci-Annie doll as a system input. The system input is how the user responds to the materials presented by the interactive delivery system; that brings us to the next element: system output.



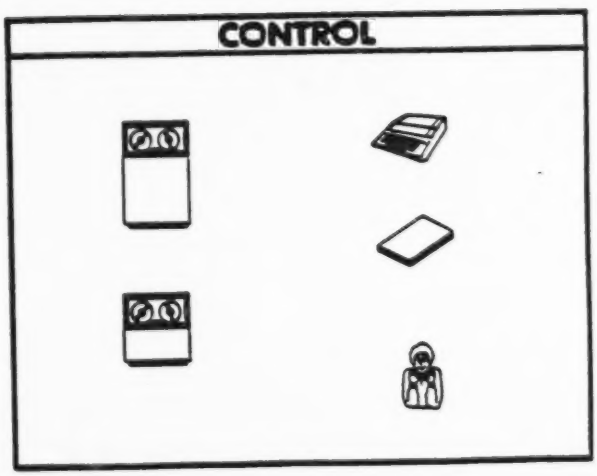
System output is primarily the audiovisual stimuli the interactive delivery system provides to the system user. Traditionally in interactive video, a video sequence is presented on a television screen, accompanied by sound. In some cases the video could be projected on a larger screen through a video projector. A less common form of output is printouts that can be used to record student data, or to provide questions or lists of reference materials. The material may come from a variety of sources -- from a computer, from a videodisc, from a combination of computer and videodisc for both the visual and audio portions. The system output is the point at which it is combined for the user.

It is the interrelationship between these first three elements of the interactive delivery system -- the user, system input, and system output -- where the interactivity that results in effective



communication takes place. It is the interaction among these elements that would be observable to the system user, and in many cases it is the description of what you expect the user to do in responding to what he sees and hears that would be the basis of an instructional design.

The two remaining elements are those that allow these sophisticated interactions to occur: the system control and system media. The system control is the portion of the interactive delivery system that controls the delivery. In this paper we are focusing on the personal computer, but the system control can be large mainframe computers, mini-computers,, personal computers, dedicated black box or dedicated microprocessors of some sort, to last but not least, the human being, whom we sometimes refer to as semi-intelligent control! In programmed instruction without the computer, such as programmed textbooks, it is in fact the user who controls the system output and provides the system input.



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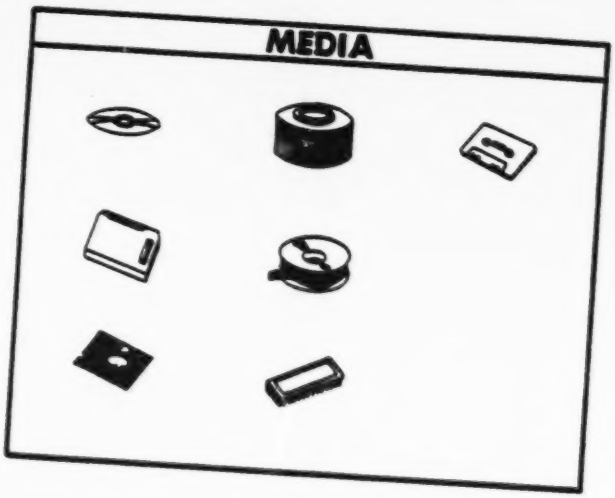
Last but not least is system media. System media is where all programs and program materials are stored. Whereas the system control is the device that allows the interaction, it is system media that stores the computer program, stores the video presentations, and provides the material. It is the system media which the interactive producer must create, usually for a specific interactive delivery system using a specific control device.



There is no difference between the elements described here as the elements of an interactive video delivery system and those elements which the original scholars such as Skinner researched, in terms of basic components; the difference is primarily in the power to do things easily that the earlier teaching machines lacked.

Let's give some examples of how these five elements are translated into current delivery systems. One of the first truly interactive consumer discs is the very popular Mystery Disc. The users of the Mystery Disc are a group of adults at a party who want to play the mystery, which is similar in style to the board game called Clue. The system input is done via the keypad that comes with the home videodisc player. The system output includes audio from either channel one or two, because we have two audio channels not intended to be played simultaneously, and standard motion and still frame graphics. System control is that of the user. There is limited built-in control in that a consumer videodisc player has the capability of stopping at predetermined points and branching to predefined chapter stops. The user responds to directions provided on the machine when the disc stops. What will be shown next on the disc and which audio channel will be heard is controlled by the user. The system media is a single videodisc with two channels of audio and chapter stops programmed into the disc. This would be an example of a typical interactive delivery system available to consumers today and in the jargon of the Nebraska Videodisc Group, this would be referred to as a Level I delivery system.

Now let's look at an interactive delivery system using different elements. In this case we'll say that our system user is an employee engaged in training, perhaps using the automobile maintenance discs developed by General Motors or Ford Motor Company. The system input is still a keypad provided, in this case, with the industrial videodisc player, allowing numeric entries and some special options. System output is again the television pictures from the videodisc with two channels of audio. System control in an industrial player is more sophisticated than that in a consumer model. Within the industrial videodisc players is an internal microprocessor that has a small amount of memory to receive programs specific to that disc. In fact the current players have a larger amount of memory and can receive multiple data dumps of programs to allow more sophisticated interaction with the user. The system control is a microprocessor, a dedicated black box built into the videodisc player. System media in this case is a videodisc containing audio on two channels and video, but also containing on one audio channel data dumps of the computer program to be used with the industrial disc. This configuration of five elements, incorporating an internal microprocessor, is commonly referred to as a Level II disc.

Another configuration would be the CPR training created by David Hon of the American Heart Association and currently being marketed by Actronics Inc. In this case the system user could be anyone wanting to learn CPR, but the disc is specifically targeted for those in health professions. The system input has a number of specialized features. It uses a light pen touched to the television screen for the primary input from the user, but there are also two mannekins, Resusci-Annie and Resusci-Baby, that convey input when the user practices CPR. System output is provided on two video screens, one screen primarily still frame and motion visuals with audio, and the other primarily computer graphics and audio. This audio comes from a random access tape, which we will mention later under system media. Additional outputs from the system work within the input devices on the Resusci-Annie at appropriate times; one closes a windpipe so that the student trying to force air into Resusci-Annie feels the resistance of a blockage. System control

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in this delivery system is done by an external microprocessor. In David Hon's prototype at the American Heart Association, it was an Apple II computer, but in the unit being marketed, the microprocessor is completely hidden from the user. System media in this case is more diverse. There are floppy diskettes which contain the computer programs, a videodisc that contains audio and motion graphics and still frame graphics, and there is an audio cassette that is used to provide random access audio to give supportive audio over still frames and over computer graphics. This system would be referred to in the trade as a Level III system, because it uses an external computer.

The advantage of using our model's five elements is that they can be used to describe current delivery systems provided by hardware suppliers and manufacturers of equipment, but also can be used to specify interactive delivery systems that do not yet exist or that require extensive customized equipment. One thing that the model demonstrates is that if someone were to develop the delivery system for CPR training today, they most likely would not use the random access audio tape recorder but would use a method developed for the videodisc that stores audio within a still frame and reads it out. The advantage of this model for describing these delivery systems is that you first describe the sort of system output you want — audio over still frames, audio over a computer-generated graphic, and so on — and it is only later that you decide on the best computer configuration, authoring systems and strategies for control. Then you look at the media storage as to what is the most efficient, cost effective, and reliable means of providing the various resources that you want for system output.

A number of the interactive delivery systems in development now have such unique ways of meeting the problems of the five elements that the Level I, II, and III designations become inadequate. The range of users is great and the system inputs being used are quite creative. One system for point-of-purchase in a mall uses Polaroid ultrasonic rangefinding equipment to detect the presence of a potential customer. A number of systems are also experimenting with voice recognition. In terms of system output, some delivery systems provide either computer graphics or graphics from videodisc, but the inexpensive and reliable technology that allows the superimposing of computer generated graphics over standard NTSC broadcast television has allowed for a great deal of sophistication in the output; anyone but the trained computer and video expert would not know whether the materials were being generated from a videodisc, from a computer, or from a combination thereof. Arcade games are capitalizing on this graphic overlay capability. System control is expanding with the availability of more powerful and less expensive computers. System media has taken a number of turns, particularly in the capability of the videodisc to provide extended amounts of audio. Previously the videodisc could provide 54,000 still frames, but as soon as one wanted to add audio over those still frames, one had to go to full motion on the disc. Consequently one was limited to 30 minutes of stereo sound. Now the digital recording of audio has made possible more efficient means of providing audio over still graphics.

TYPES OF COURSEWARE

The interactive delivery system hardware does not provide the instruction; persons must create training for users to receive on the system. Before describing how to make instruction for interactive delivery systems as defined by the five elements previously discussed, it would be useful to describe the various types of courseware one can create. I will describe them, not necessarily in order of importance, but in an order which I hope will provide a useful perspective.

One type of computer-based interactive video courseware is management courseware. Management courseware can do such things as testing persons and creating a diagnostic profile of strengths and weaknesses; it might then place them in appropriate learning groups or determine how they would proceed through a set of courseware. I mention this first not because I think it is the most important, but because it is under-utilized.

Another type of courseware is tutorials, which follow the model of the tutor and tutee. A large percentage of courseware falls into this category. Information is presented, some simple means is used to verify comprehension, and the tutor proceeds with more information.

The strength of computer-based education and an application for which a lot of courseware is developed (though not always enjoyed by the students) is that of drill and practice. When we talk of computer-based education, the ability of the computer to give endless number of multiplication problems, for example, is described. Drill and practice is just what it says, drilling the student

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time after time until he has acquired the skill with the required level of proficiency.

Another set of courseware simulates real activities. . . driving a car, operating the control panel of a nuclear reactor, whatever the case may be. Arcade games are good examples of one form of simulation, and many of those games do in fact have an educational value. While simulation has been used successfully in many fields, it is best known in aircraft trainers, where the extremely high cost of using the actual equipment, combined with the risk of training errors costing lives as well as equipment, has led to the use of large, expensive simulation machines. The ability of interactive delivery systems to efficiently provide very lifelike simulations is one of their strengths.

Each of these types of courseware — management, tutorial, drill and practice, and simulation — should be integrated into an interactive delivery system, but often courses focus on just one. Hence evaluating courseware is critical.

THE INTERACTIVE COURSEWARE TEAM

By now you have no doubt surmised that the many skills needed to create good interactive courseware necessitate a team approach. The interactive courseware team needs to first include the interactive video producer, the person who is in charge of the overall project. Like the producer in Hollywood, he or she is the person who makes it happen, is probably responsible for obtaining and distributing funds, and is the communication link between management and staff. This is the person who is responsible for integrating this training into the overall system of the company. In many respects, this is where the buck stops.

Next is the instructional designer. In many ways the instructional designer is the project manager, the person who is in charge of the operation and the team that creates the interactive courseware. The instructional designer is the one who breaks the problem down into the cognitive objectives (those dealing with information and knowledge), the affective objectives, (desired attitudinal changes),and the psychomotor objectives, (the performance skill that the interactive producer wants to teach).

The instructional designer will require a series of specialists to round out the interactive video team. One will be the content specialist, preferably not just someone who knows the subject matter but someone who is involved in conveying that information to other human beings. He or she might be regarded as a master teacher. In interactive video, unlike some other media systems used in training, we are not only interested in the accuracy of specific course content, but also how one would explain it to different audiences. Knowing errors that students commonly make is helpful because these can be detected and corrected in various ways with an interactive delivery system. The content specialist provides the subject matter knowledge in the area but also knowledge of how to teach the specific target audience.

INTERACTIVE VIDEO TEAM

- I.V. Producer
- Instructional Designer
- Content Specialist
- Writers/Editors
- Media Producers
  - Still/Motion
- Packager – System Integration
  - Continuity, Physical Layout,
  - Operate Authoring System,
  - Co-ord. Program Until Mastered

• EVALUATION INTEGRATED INTO ALL JOBS

In interactive delivery systems many things have to be written -- video scripts, texts, dialogues that appear on screen as well as those that take place between the user and the system. These require different writing skills, so an interactive video team might include several writers, each specializing in one type of writing; all would submit their work to editors who look for internal consistency and make the package appear on screen as an integrated delivery system.

Much of the material generated by writers must be produced. Media production is usually divided among graphic artists for still production; video artists for motion sequences; computer programmers for designing equipment control. The media producers take the materials that the writers and producers created, based on the instructional design, and turn them into the resources that will be used by the interactive delivery system, i.e. the program that will be used by the system controller and the media that will be the source material.

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Because so many diverse forms of media are used in these projects and delivery systems can have many forms of input and output, requiring different forms of media control, we need a systems integration component on our team. This person packages the courseware for interactive delivery systems; he or she might be a video editor who puts source tapes in proper order for the pressing of the discs; this person might either operate an authoring system or program the codes that would go into the delivery system. He or she would be the last person to touch the courseware before it is put on the system for testing and then use.

EVALUATING COURSEWARE

What guidelines can you use when evaluating interactive courseware? First, is it an appropriate use of the technology? We spoke previously of the five elements of an interactive delivery system. These elements can be mixed and matched in very different ways. When is it appropriate to use a voice input device versus a touch screen? What sort of output is appropriate?

Another consideration when evaluating courseware for sophisticated interactive delivery systems is the relationship of all the materials. When we described the team that creates courseware, we saw that they are creating video messages, graphic messages, dialogues that will be observed by the learner, and dialogues in which the learner will participate. What is the relationship of all the media forms within the courseware? Is one form inferior to the others in quality, thereby detracting from the whole? The courseware might, for example, have excellent design and questioning strategies but poor video for demonstration and reinforcement.

Another aspect to consider is ease of use. You will hear systems described as "user friendly" or in terms of "system transparency," meaning how invisible/obtrusive is the delivery system during use. Many experiments with early teaching machines and some of the research that took place with computer aided instrucpion in the 1970's alluded to the inability to completely judge the effectiveness of these devices in learning because of the interference of the delivery system itself. In early computer based education, which was very text oriented and necessitated use of a typewriter keyboard, often that posed a barrier that confounded the machine's ability to be an effective conveyor of information.

Another factor when evaluating courseware is the quality of the programming, again using the term "programming" with reference to multiple disciplines: the quality of the television program, the quality of the graphics and possibly a slide program, the quality of the computer control, in fact the quality of the basic computer program. In evaluating these, the more knowledge you have of each medium and its limitations the better, but you need not be a video producer to know what is an effective television program. Although you may not be an excellent "hacker," through use you can judge the response time, ease of use, and other aspects which are usually translated into the quality of the program.

And then one must consider the quality of the instructional design, the pedagogical approach that is taken. This I list last, but it is first in importance; too often courseware takes advantage of the technology available in terms of the hardware, but does not take advantage of the research available in terms of a systematic approach to creating training. If we use the computer to provide drill and practice on the memorization of terms, it is important that we apply the proper learning theory about memorization. If we know that the short term memory of an individual is seven items, plus or minus two, yet we design drill and practice segments where we attempt to commit thirty-three items to short term memory, the system is capable of delivering such instruction but the human being is incapable of receiving it. Sophisticated hardware is no substitute for good instructional design.

Given the difficulty we have had in producing successful computer based education and in creating successful video, one can anticipate the difficulties involved in combining the two. The introduction of the personal computer and random access video has made available to the courseware developer delivery systems capable of delivering the sophisticated training that was envisioned by the early researchers. Yet our systems of creating courseware have not caught up with our technological capabilities. Nevertheless the potential when combining videodisc and microcomputer technologies is great: when combined successfully to present courseware based upon solid instructional design, they will produce more effective training than ever before possible.

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Appendix B

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